A GIS for 3D Pipeline Management

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Abstract

Smart pig is one of the best tools available to measure pipeline integrity: identifying corrosion, metal loss, mechanical defects. Risk management strategy can thus be developed to help prioritize anomalies hence avoiding expensive systematic pipeline replacements. A 3D GIS offers a media to correlate data from various inspections by effectively identifying the geographic location of anomalies (point or linear events) instead of by approximation (interpolation) in the 2D approach. The project takes place in France where operators demand a 3D pipeline model incorporating original "weld book" data. Pipelines are registered in space and thus profiles can be generated automatically which are particularly useful for the incessantly re-routings. This presentation will exhibit the project background and requirements as well as the workflow employed. It will also discuss the feasibility and effectiveness of implementing such a 3D model on ArcGIS.

Introduction

While pipelines are the safest means of transportation, their effective maintenance have been of great concerns to many pipeline operators, regardless of national or federal regulations, due to the high costs of O & M, safety and possible environmental impacts. A good pipeline management is to decide what action to take at the right time so as to protect employees, the general public the environment and the pipeline itself.

Corrosion is a major reason for aging and deterioration of an underground pipeline. The cost of corrosion prevention is highly related to the preservation of the value of the pipeline. Integrity management programs are set up and to be set up in different parts of the world to optimise corrosion control and to implement corrosion prevention strategies.

The most cost-effective integrity management program should include in-line inspection (ILI) and direct assessment. Smart pig* (ILI) that detects and locates, anomalies, corrosion or leaks, is capable of measuring the real distance travelled (the chainage in 3D) between the origin of the pipeline till the flaw detected in question. It is very valuable to locate flaws before they become critical and cause pipeline failure (either leaks or rupture). The principal difficulty is "find it and fix it".

** Pipeline pigs are devices that are inserted into and travel throughout the length of a pipeline driven by a product flow. They were originally developed to remove debris and deposits which could obstruct or retard flow through a pipeline. Today pigs are used during all phases in the life of a pipeline for many different reasons. A smart pig is capable of detecting certain irregularities or anomalies in the pipe wall. The ability of the technique to find corrosion flaws larger than a certain size (typically, 10 percent of pipe wall thickness) makes it valuable for locating flaws.*

figure 1. a smart pig

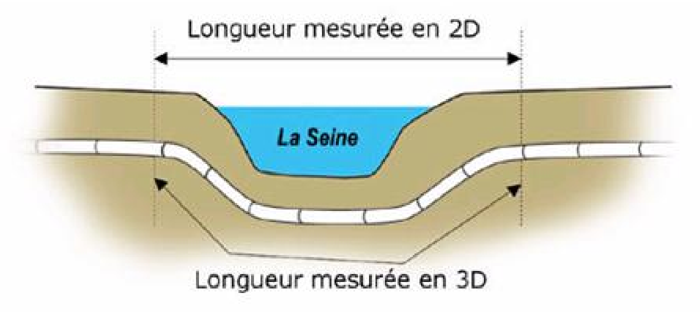
Find it and fix it

Data generated from smart pigs (or instrumented pigs) are not enough to give the exact geographic location of the points to dig. The words "Find it" are of vital importance. In case of emergency, one has to determine the corresponding location such as name of town, street or address to reduce response time.

Pipeline data

Pipelines traverse across country, which go under, over or near highways, rivers, up and down hills following the topography and are subject to significant change of altitude. Distance in 2D (map distance) is very different from the real distance in 3D (measured by a smart pig) linearly along the pipe axis.

Distance measured in 2D from maps



Distance in 3D

figure 2. difference of distances in 2D et in 3D

Before intervention, one has to know what pipe is to be replaced/repaired, curved or straight, its thickness, diameter, length and most of all, where to dig. In order to determine the location for operations with precision and the attributes of the pipe in question, it is necessary to possess a data base of the pipes in 3 dimensions.

Pipeline management in 2D

Most of the pipeline GIS in the industry are managed in 2D with features as “pipe segments” (that could contain thousands of pipes). In case of leakage detected by a pigging process for instance, le probable intervention area is large and unreliable due to linear uncertainty. The costs of inspection or intervention have a considerable range depending on the number of digs required for direct examination. Wild preliminary digging means high cost and inefficiency.

The performance with a 3D database

In a 3D GIS incorporating the data of weld books, individual “pipe” is modelled as a feature. A pipe is defined as the shortest segment between 2 welds. Weld books are paper documents indicating all the attributes of each pipe at the time of construction of the pipeline (some date back to post World War II era).

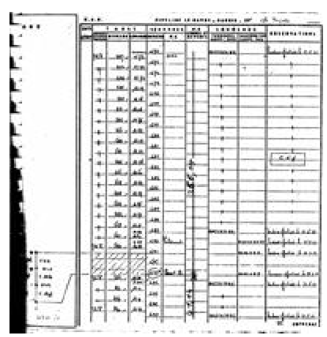


figure 3. extract of a weld book

Response time is improved because the location is more precise. Data (distance travelled by the pig and the corresponding flaw) issued from smart pigs can be entered directly to the 3D GIS and located spatially thanks to the 3D pipeline and geographically according to the base map.

Here is an example of a pig run on corrosion and metal loss (metal tearing). The flaws are displayed geographically along the pipeline.

Figure 4. " metal loss"(red point) and" corrosion"(blue point) - relative point events, are displayed geographically along the pipeline

Moreover, equipment necessary for operations in the field, which depends on the characteristics of the particular pipe (attributes from the weld book), can be programmed.

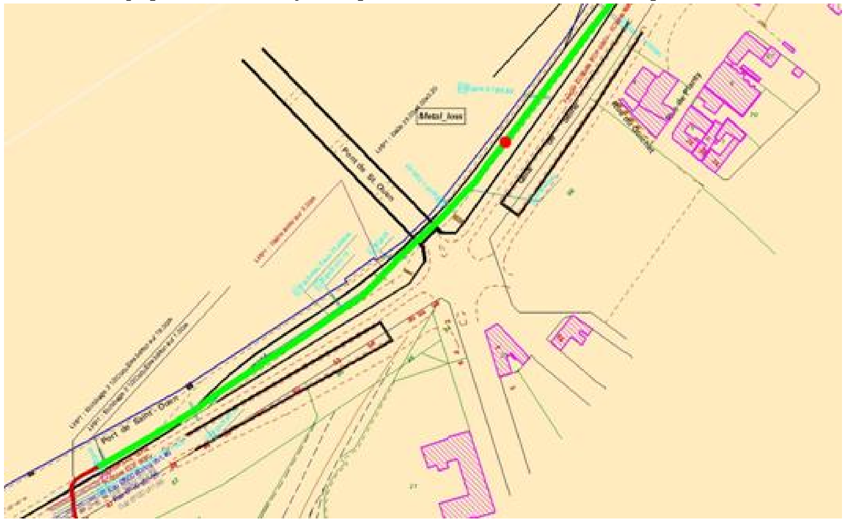


Figure 5. Suspected Flaw(in red) located with the help of the base map, field crews are ready to work

Absolute and Relative Events

It goes without saying that the most critical parts of any pipeline integrity program or risk management is the collection of accurate information on the present condition of the pipeline. Information on the pipeline's surfaces can be collected by excavation or via a smart pig.

While direct assessment in the field by excavation can be modelled and placed on the pipeline graphically or digitally (GPS coordinates) as absolute events, data issued from smart pigs have to be modelled as "relative events" (point or linear) along the axis of the pipeline. In a GIS, an event, be it point or linear, can be placed relative to the network by means of a distance (real) from the smart pig. Hence a 3D model of the pipeline is indispensable in order to keep accurate location information on the events so that risk management can be effective. As with any analysis, the more complete and accurate the data, the more accurate the final results become. Incomplete data will increase data acquisition costs and possibly dilute risk results. A primary objective in any risk model should be to locate the most current and accurate information.

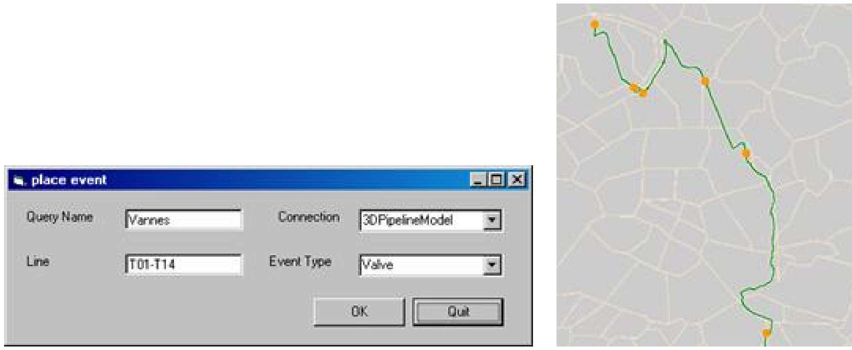


figure 6. placing absolute point events: valves

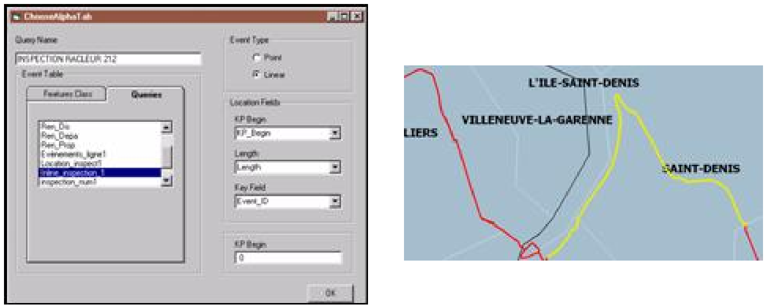


figure 7. placing relative linear events : ILI (smart pig run) displayed in yellow

The workflow for the creation of the 3D GIS

1. Establishment of pipeline in 3D
   Data is collected in the field by means of electromagnetic devices and land surveys. The position of the pipeline (x,y) are known. The layout of the pipeline in 3D is established from the ground altitude of the detected pipe, cross-sections, direct assessment and re-routing data.
2. registration of pipeline sections
   Sections are registered in space by means of 2 homologous points (valves) which are identifiable both in the field (and surveyed) and by the smart pig. A difference between the length of the surveyed pipeline section and the length given by the smart pig should be distributed even over the entire section (applying a scale factor). This difference can be due to cartographic projection, uncertainty of the pig measurement and uncertainty of altitudes of the pipeline.

3. segmentation of sections
   Information of the weld book is to be incorporated in the GIS. Segmentation can be done dynamically as a query. Weld points are placed graphically according to the length of each pipe
4. quality control
   Checks are carried out to ensure the matching of all lengths.
5. create output file
   Output ascii files can be created to include coordinates of each pipe and the corresponding attributes.

Our customers' requirement: a 3D pipeline model

Line: is the pipeline, a principal element of the model. A pipeline is composed of *sections*.
Physically, a pipeline is composed of "*pipes*", segment between 2 welds. These pipes are materialised by the weld book (chainage, pipe length, wall thickness and so on) established during construction and re-routings.

"Line" and "section" are classes without geometry. Their geometry is derived from "*pipeline_layout*" and "*section_layout*" respectively.

"*Section_layout*" are the fundamental class with geometry of the pipeline model. All the vertices of this linear geometry are in 3D (x, y and z).

"*pipeline_layout*" is derived from "*Section_layout*" by aggregation. Any re-routings and resurveys are incorporated only in *Section_layout*. P*ipeline_layout* will take the geometry of the incorporated re-routing automatically.

All the facilities of the asset such as *valve, cathodic protection,* are represented by point "*events*"

Physical inspections such as *metal_loss, corrosion* and *cracking* are modelled as point events.

InLine_Inspection, coatings, casings and even *pipes* are modelled as "*linear events*".

All relative events are placed according to the distance from a known point such as the origin of the pipeline. Their geographic positions can be adjusted after a resurvey (with a more accurate instrument for instance).

The 3D GIS for risk assessment and decision making

Good decision can be made only upon good and reliable data. Very often, the action to perform maintenance on a pipe was left up to the decision of a limited number of people, depending solely upon their personal experience or an even more limited amount of information (of different qualities and reliabilities) before them. In some cases, data will need to be transcribed from historical records (for instance, leak and leak history). A general geographic view of all data on a common framework, a GIS with precise geographic location can help pipeline operators analyse the interaction of events and identifying probable risks. However, the precision of geographic locations are dependent on the quality of the data used, i.e. a pipeline modelled in 3D gives better precision on the locations of flaws and hence better decision making.

Moreover, to simplify the maintenance of the data, the model should be able to incorporate newer information as new events. The GIS should be capable of furnishing as much information as possible to evaluate the overall risk of all pipelines in the system in a logical and traceable manner, and visually display along the pipeline the results for analysis.

Once the database is created with location of the pipeline in space (3D), spatial queries including or queries on attributes can be carried out such as

- finding the attributes of a particular pipe

- locating all the pipes between 2 chainages (mile-posts, real distances) furnished by smart pigs
- locating the concerned parcels and the land owners

Cross-sections can also be generated using the 3D data by indicating the desired segment by means of a rectangle.

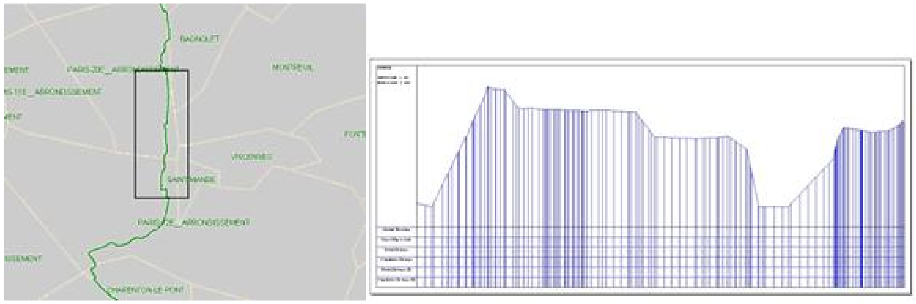


Figure 8. cross-section generated from the 3D GIS

Cross-sections and probable risk points

Studies indicate that in an accident of a natural gas line, some liquid bypassed the drip and continued through the pipeline, further weakening the line, including the eventual rupture site. The reason being that the drip became partially clogged upstream of the rupture location. A bend in the pipe had created a low point in the pipeline where liquids and other residue accumulated and caused corrosion. Potential weaknesses can be identified with the help of examining the cross-section of the pipeline indicating relative low points.

3D Model and ArcGIS

Studies have been carried out on implementing our 3D model on ArcGIS. We found several possible solutions:

- by adding a value M (Measure or chainage) at every vertex of the polyline (Section_Layout). This way, the geographic coordinates of point or linear relative events can be located by the distance given by the pig measurements.
- By adding a value Z (altitude of pipe) at every vertex of the polyline. This way distances are calculated from the origin to the position of any relative events.
- By using both M and Z values.

An advantage of using Z is that in case of “re-routing” of pipeline, all the other Z values over the line can be conserved.

Whereas if we use M, which is a derivative from Z, all values of M situated down-stream the “re-routing”, have to be updated accordingly in order to conserve the integrity of the data.

We are still working on implementing functions such as outputting different sorts of events as “spatial queries” in ArcGIS. This is a very challenging task as the success gives rise to a flexible and effective application on 3D pipeline GIS Management.

Future

Developing an optimum approach that includes both inspection and corrosion prevention strategies is vital to the future safety and the cost-effective operation of transmission pipelines. The overall goal of the pipeline industry must preserve the pipeline as an asset. A pipeline GIS in 3D is a critical part of any strategy. Significant savings are possible by optimising the inspection and corrosion prevention strategy.

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Biography

Cindy Pubellier is chief technical executive and vice president of IDS, France. She has more than 15 years of experience in the GIS arena in various countries. A land surveyor, she earned her B.Sc. (Honours) degree in surveying and mapping sciences in London. Before setting up the activities in IDS, she was the technical manager of automatic mapping production for Michelin, where she supervised the first digital maps and atlases of Michelin.